Snow Algorithm Lab Exercise Case Study
DLOC 2008

Objectives:

1. Become familiar with the ZS algorithm.
2. Understand why WSR-88D precipitation estimates are sometimes over- and underestimated.
3. Analyze where you think the ZS algorithm is over- or underestimating precipitation.

1) Objective: Familiarizing yourself with the ZS algorithm.

The ZS algorithm uses the Hybrid Scan Reflectivity product as its input data.

Remember that the Hybrid Scan Reflectivity Product chooses the best reflectivity to convert to precipitation. What are the three main criteria for accepting a reflectivity for each bin in a Hybrid Scan Reflectivity Product?

Beam Blockage ≤ 50%
Not in an exclusion zone
REC clutter likelihood ≤ 50%

You recall the ZS algorithm equation.
$Z = aS^b$ where a, and b vary according to region. Here is a map of the regions.

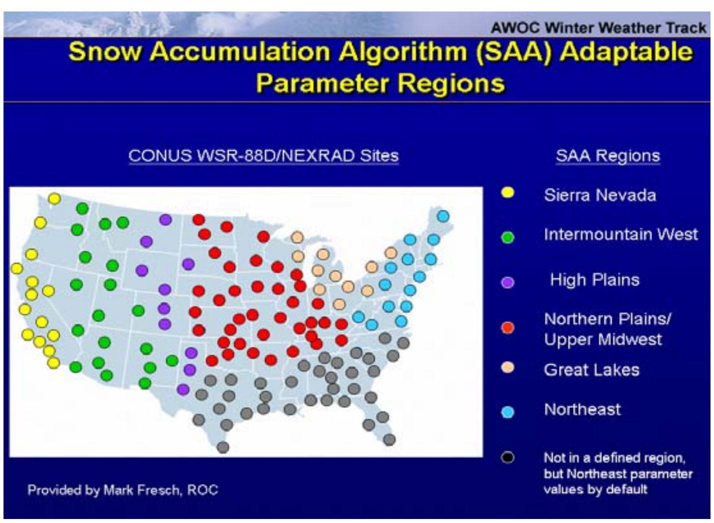

Figure 1 Snow Accumulation Algorithm Adaptable Parameter Regions

We will be using the Pueblo radar in this lab where $Z=130S^{2.0}$.

The ZS has a range correction factor:

S corr = C1 + C2R + C3R^2 where R is the range in km, C1=1.097, C2=.0069, C3=0, R represent coefficients found in the HCI, adaptable parameters section for the ZS algorithm. There are six regional range correction factors. Here is a graph of range correction vs. range from KPUB.

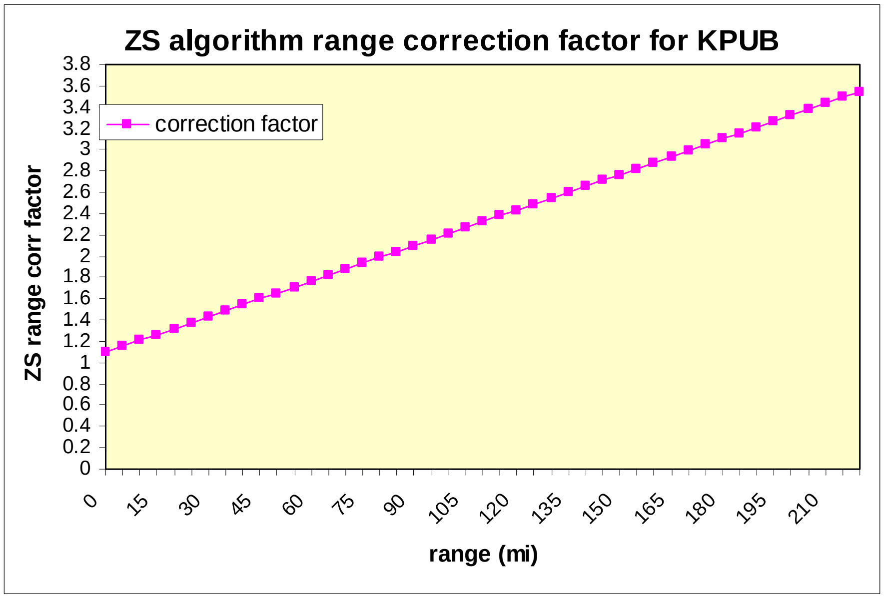

Figure 2 Range correction factor derived for the KPUX radar. Note that C3=0.

The ZS algorithm multiplies the liquid equivalent amounts by the correction factor. The range correction factor is dependent on range and the coefficients (C1 to C3) only.

The **ZS algorithm products** in AWIPS are:

1. One hour Snow Depth (OSD) – uses a snow ratio (11.8 to 1)
2. Storm total Snow Depth (SSD) – same snow ratio as OSD
3. User Selectable Snow Depth (USD) – same snow ratio as OSD
4. One hour Snow Water equivalent (OSW) – Snow Water Equivalent (SWE)
5. Storm total Snow Water equivalent (SSW) - SWE
6. User Selectable snow Water equivalent (USW) – SWE.

2) Objective: Potential limitations and errors in the ZS algorithm

1. Assumption of dry snow – brightbanding

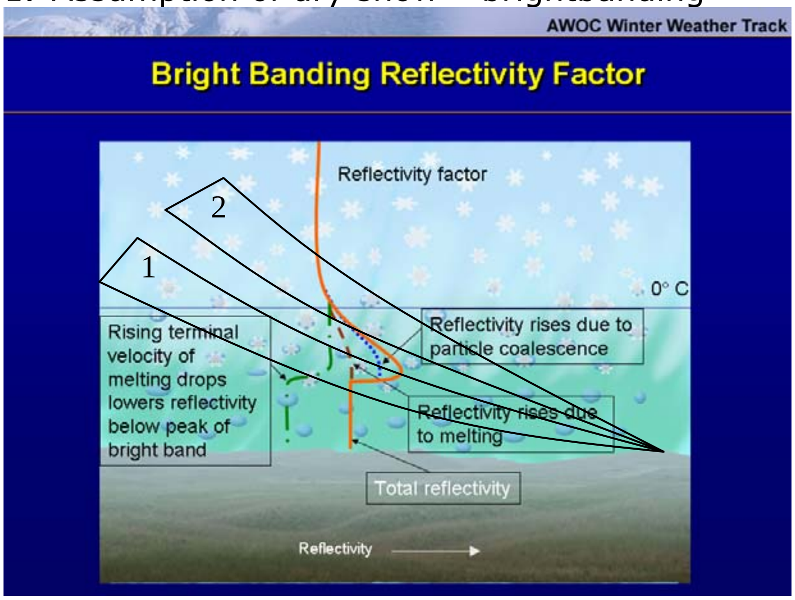

Figure 3 Brightband schematic[1] Note that the reflectivity factor in the orange curve, and its contributions (green dash/dot, dashed red, dotted blue) represent vertical profiles where reflectivity increases going to the right and height increases going upward. Notice that the reflectivity factor starts to increase at -1 to -2 C as water coating on snow lingers longer before freezing. Note that precip overestimation occurs even if the top of beam 1 or the bottom of beam 2 sample the melting layer.

2. Beam overshooting

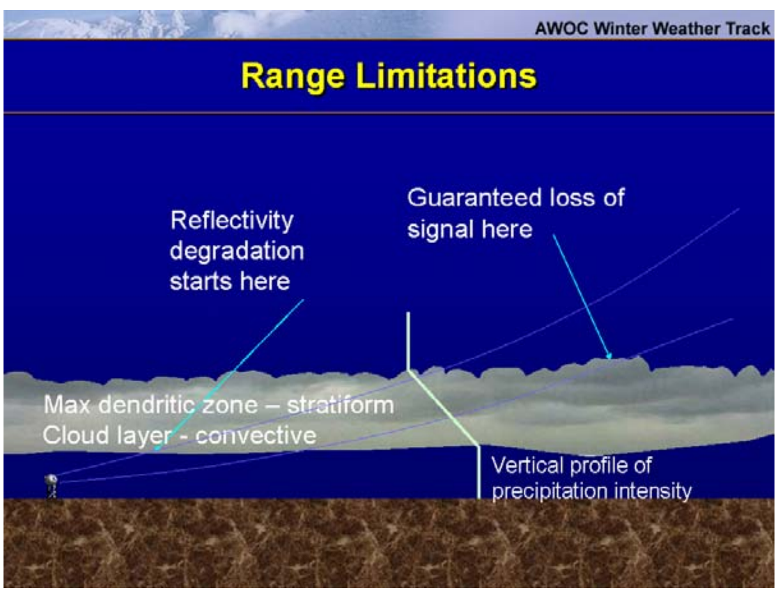

Figure 4 A schematic of the range limitations.

Remember that the ZS algorithm applies a range correction in an attempt to account for range limitations. But it cannot account for localized patterns in a vertical reflectivity profile. Anticipate where you would see orographic, convective, or other sub-beam clouds.

3. Sub-beam evaporation/sublimation

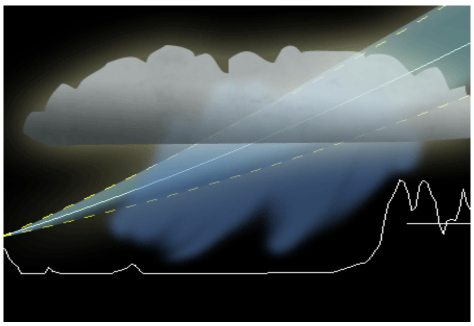

Figure 5 A schematic of sub-beam evaporation/sublimation

This problem is most common when there is sub-beam dry air such as in downslope and low elevation areas. These areas may have lower annual precipitation totals such as that shown in the map below

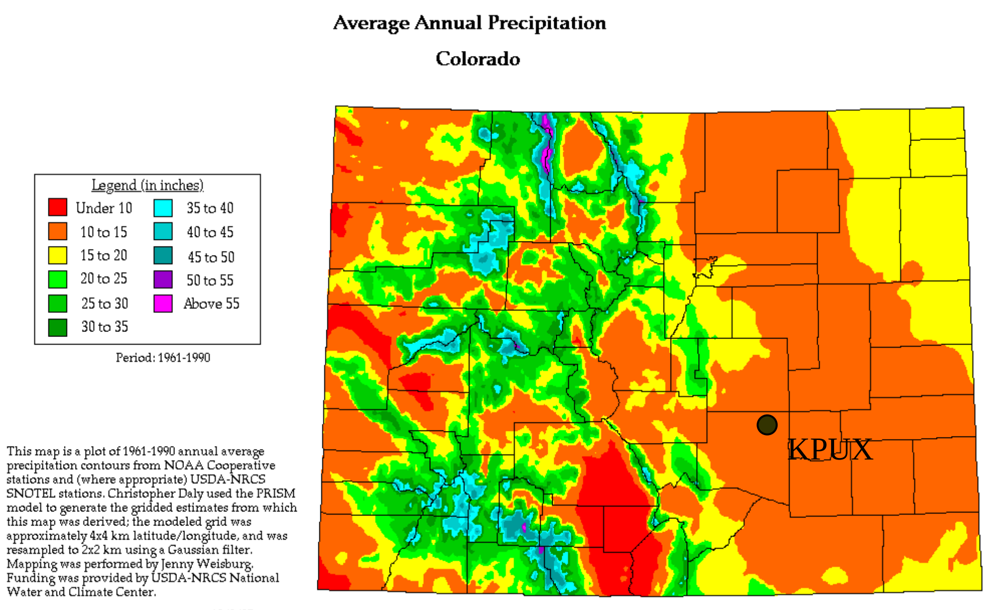

Figure 6. A map of annual precipitation for Colorado to highlight areas conducive to evaporation vs. orographic precipitation enhancement.

Not every precipitation event will result in sub-beam evaporation in the climatologically dry areas. Keep aware of atypical precipitation events.

4. horizontal displacement of falling precipitation

Under strong sub-beam horizontal wind conditions or areas of strong sub-beam vertical wind shear, you may not observe the precipitation that drifts horizontally away for long distances before reaching the ground. Lee side spillover of orographic precipitation is an example.

Recall from Topic 5 these other ZS limitations:

1. Cannot discriminate between rain and snow.
    a. Will the ZS algorithm over- or underestimate liquid rain if the beam is sampling rain?
2. accumulation is not automatically reset at the RPG
3. snow-to-liquid ratios are incorrect
    a. How many snow-to-liquid ratios can you apply at once?
    b. Melting snow at ground affects the ratios
4. Add impacts of Hybrid Scan Reflectivity product when there is beam blockage.
5. Incorrect ZS (a & b coefficients) due to precipitation particle shape diversity.

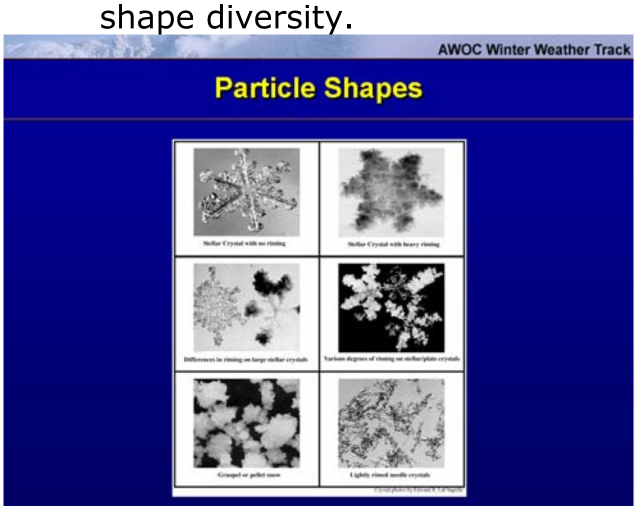

Figure 7 Various precipitation particle shapes can often impact reflectivity factor in unknown ways.

The exercise

You will be transported to the Pueblo, CO CWA back on 30 January 2005. Now, make sure your local time is set to 0600 UTC. You will now follow through the last three objectives as you go through the exercises. Work in your lab teams.

Weather Synopsis:

A low-latitude closed midlevel low is moving through the Four Corners area. In the Pueblo CWA, temperatures in the eastern Plains are just a little over freezing while the higher elevations are subfreezing. Low-level moisture is much higher than normal for this time of year. Winds above the surface (1km AGL) start out from the southeast.

3) Objective: Analyze where you think the radar is over- and underestimating precipitation (SWE).

Use figure 9 to draw contours where you believe the radar is over- or underestimating precipitation. Label each contour by the type and the direction of the error.

Important measurements to make: Use a nearby skewt from Denver, or a local RUC40 sounding for point F (KPUB). Then use figure 8 to help you fill this table out. All heights are in kft MSL, distances in mi or nm, just like the cursor readout. Load a DHR and 0.5° reflectivity product on the same panel.

Table 1 Reference of heights and distances from KPUX

Feature	height		Distance
Height of the +3° C level		Distance the top of the 0.5° beam reaches this height	
Height of the -1° level		Distance the bottom of the 0.5° beam reaches this height	
Height of the -3° C level		Distance the top of the 0.5° beam reaches this height	
Height of the -12° C level		Distance the top of the 0.5° beam reaches this height	

Method for marking potential overestimation:

1. **Draw and label a contour where you think bright banding induced errors may.**
   - From table 1, contour the distance you found for the +3° C level on figure 9.
   - From table 1, contour the distance you found for the -1° C level on figure 9.
   - Everything in between is subject to bright banding errors for the 0.5° slice. Label accordingly.

2. **Draw and label a contour where you think sub-beam evaporation is likely.** Look for areas that may be in downslope low-level flow or that show > 2° C dewpoint depressions. Areas close to the radar may show decreasing reflectivities as you lower the elevation (provided it's not bright banding).
   - To do this, Overlay 0.5° reflectivity and high res topo on a new panel. Then plot METARs and use the volume browser to subtract Temp from dewpoint for the RUC40 surface layer. Add the 1 km winds from the RUC40 to find areas of downsloping.

Method for marking potential underestimation:

1. **Outline the area where you may be overshooting the dendrite production layer (the -12° to -16° C layer)**.
   - Contour the distance you found for the -12° C layer on figure 9.
   - Areas outside your contour are where your lowest beam is not sampling this layer well.
2. **Outline areas where you expect upward motion and clouds from temperatures -3° to -12° C**. There is riming, aggregation and needle production in this layer. Your radar beam top extending above these layers will cause you to miss some of this precipitation production. Areas most likely to experience this would be in favored topographic upslope.
   - Contour any areas on figure 9.
   - Make sure these areas are further than the distance you found for the -3° level in table 1.
3. **Outline areas where you expect the Hybrid Reflectivity product (DHR) to be forced to use higher elevation slices due to beam blockage or other reasons.** These areas are less likely to accurately sample near ground precipitation. For the areas you outline, what direction do you think is the error?

We have not considered the impact of precipitation particle shape on potential errors. We cannot without any ground truth of snow flake shape or type but we can discuss this error source in the lab.

Some areas that you've contoured may show conflicting over- and underestimation potential. You're confidence on SAA performance may be less in these areas. Other areas may give you more confidence.

Adjust your analysis error and most likely origins for that error based on ground truth reports.

Upon finishing your contouring, you may find that your analysis shows areas where you'll be confident of the sign of your precipitation error while others you may see conflicting signals. To help you out, we'll provide you with time series from Colorado Springs (KCOS, figure 8), Pueblo (KPUB, figure 11), Trinidad (KTAD, figure 12), and one SNOTEL site, Whiskey Creek (figure 13). Do these time series agree with your analysis? For those that do not, what do you think the source of the discrepancy may be? Could it be an area of conflicting sources of possible error? Adjust your analysis accordingly.

Make a **short term forecast of ZS algorithm** error at selected stations. Use your analysis to make a forecast of whether you believe the ZS algorithm error for the entire event, 29 Jan, 12 UTC to 30 Jan 15 UTC will be overestimated, underestimated, or within the ballpark of the observed liquid equivalent. On figure 7, there are several stations marked with a number and a snowflake symbol. Make your forecast for these stations by labeling the following on the figure:

O = significant overestimate of the ZS algorithm; it was off by roughly +25%.
U = significant underestimate of the ZS algorithm; it was off by more than roughly -25%
G = Good estimate by the ZS algorithm; it was within ±25%.

I will show the observations at the end of the lab and discuss the results with you.

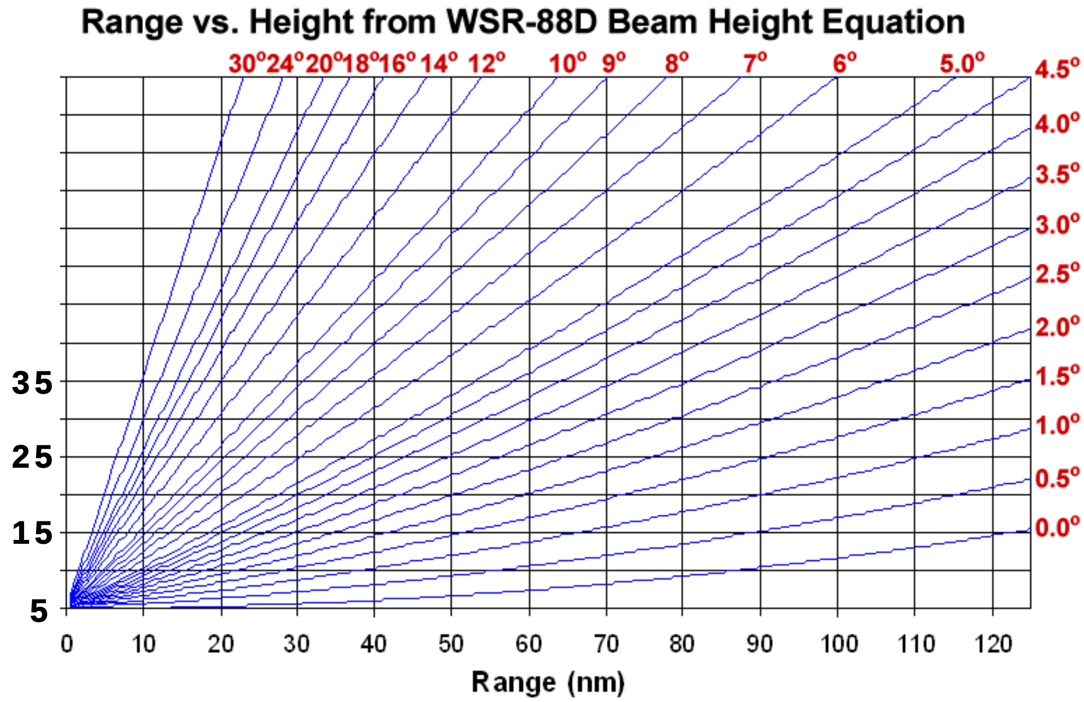

Figure 8. VCP 11 chart. Heights are in kft MSL for the KPUX radar. Use the chart to estimate beam top, bottom height and relate to range from radar.

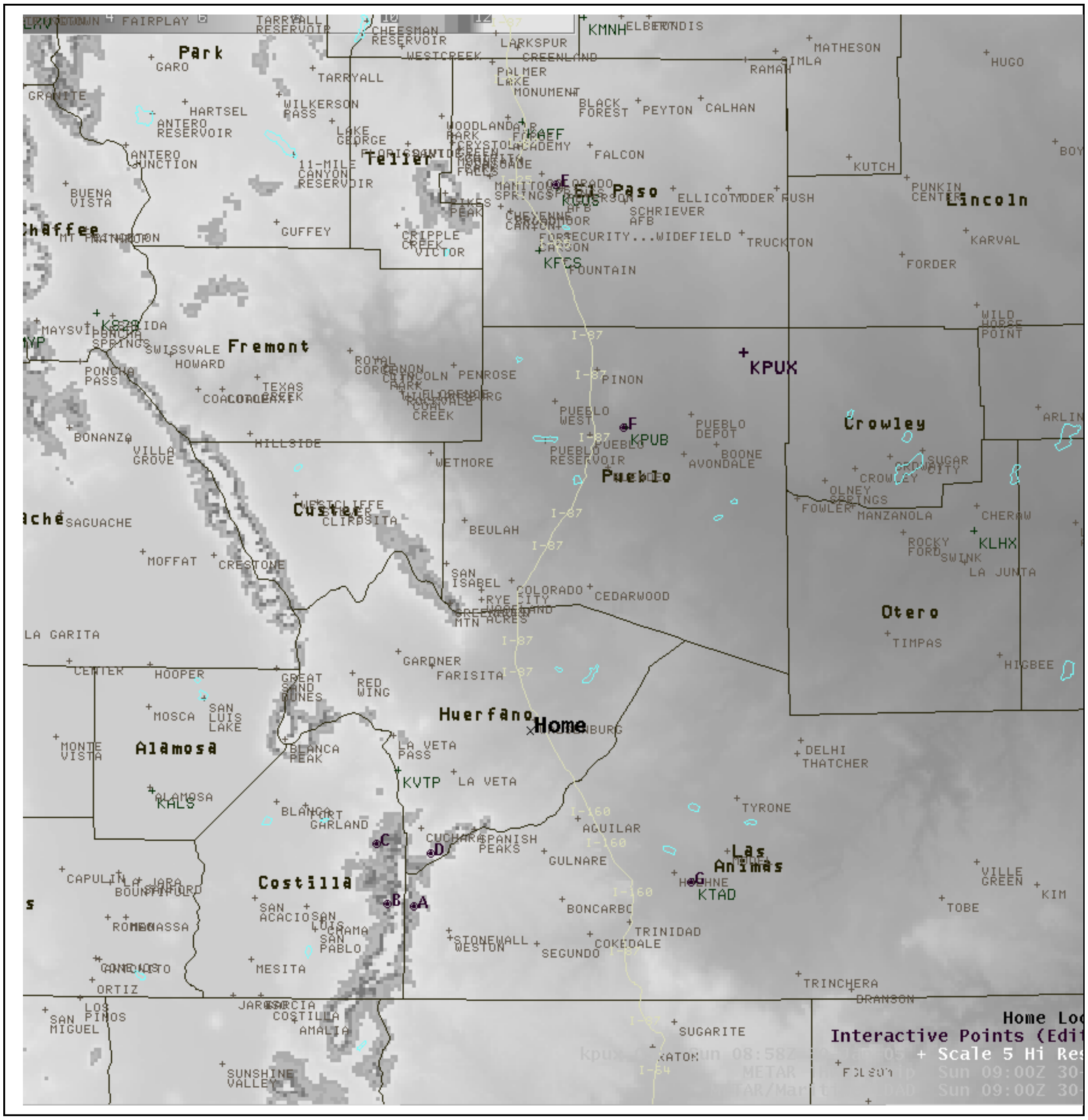

Figure 9. High resolution topography map of south central Colorado. The individual white letters represent target observation stations of interest (SNOTEL or ASOS). The map shows towns (beige), County names and borders (yellow), lakes (cyan), METAR sites (green), interstate highway (brown).

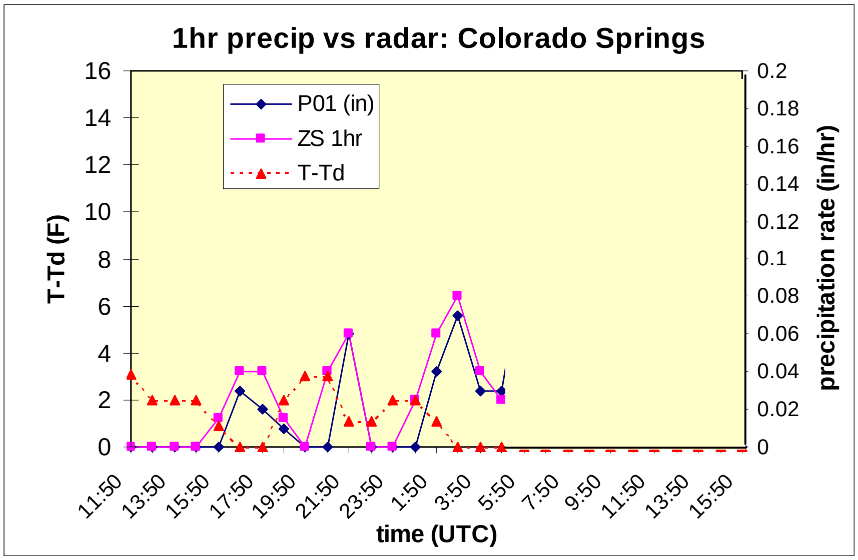

Figure 10 Time series of one hour precipitation from KCOS vs. one hour ZS algorithm output from KPUX. KCOS is also labeled point E in figure 9.

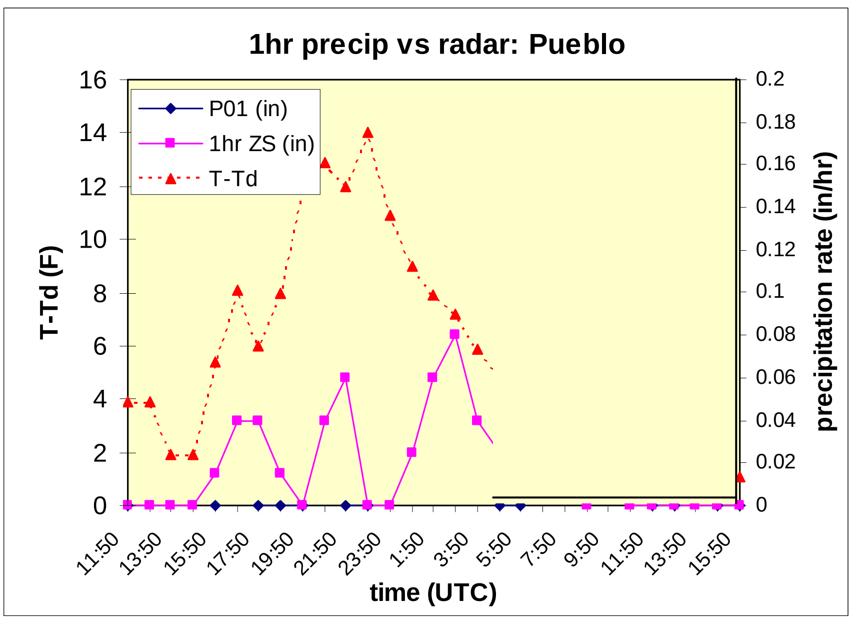

Figure 11 Time series of one hour precipitation from KCOS vs. one hour ZS algorithm output from KPUX. KPUB is also labeled point F in figure 9.

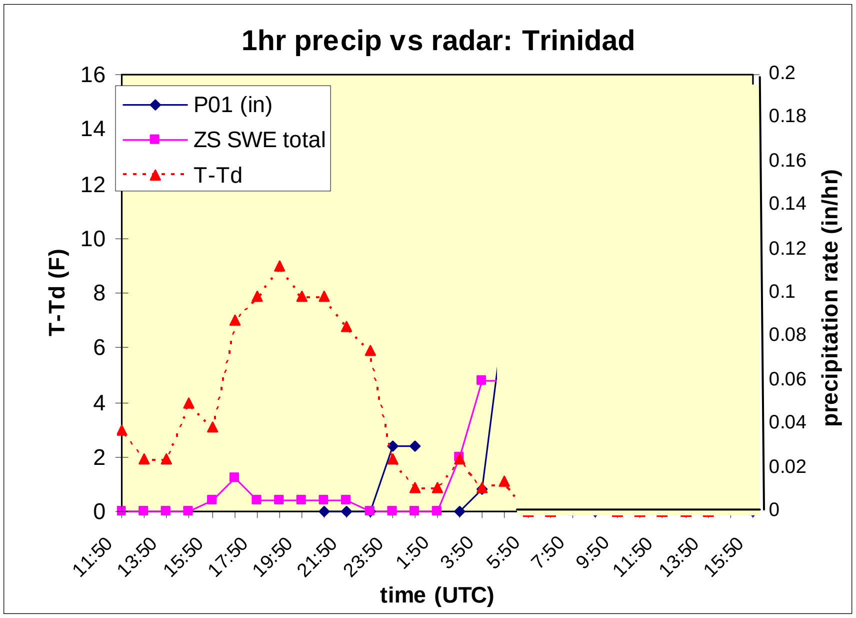

Figure 12 Time series of one hour precipitation from KTAD vs. one hour ZS algorithm output from KPUX. KTAD is also labeled as point G in figure 9.

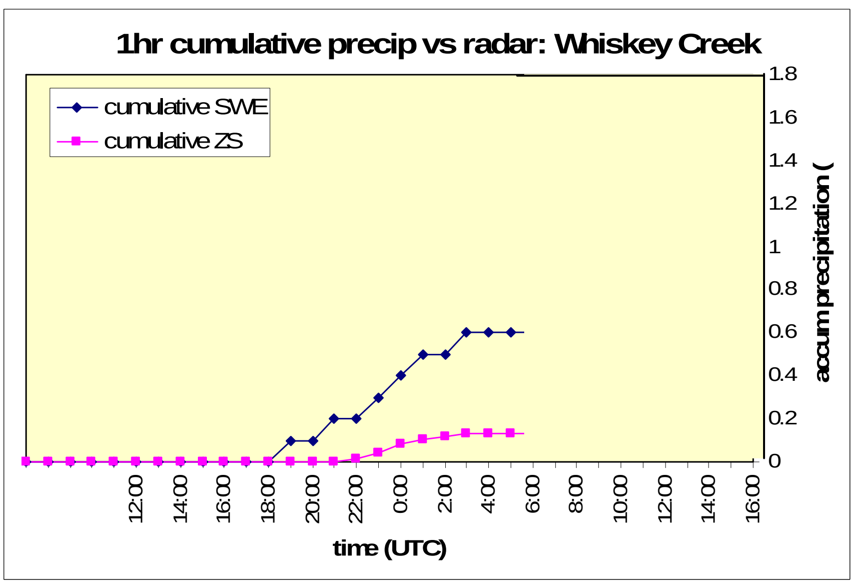

Figure 13 Time series of cumulative precipitation from Whiskey Creek vs. one hour ZS algorithm from KPUX. Whiskey Creek is labeled as point A in figure 9.